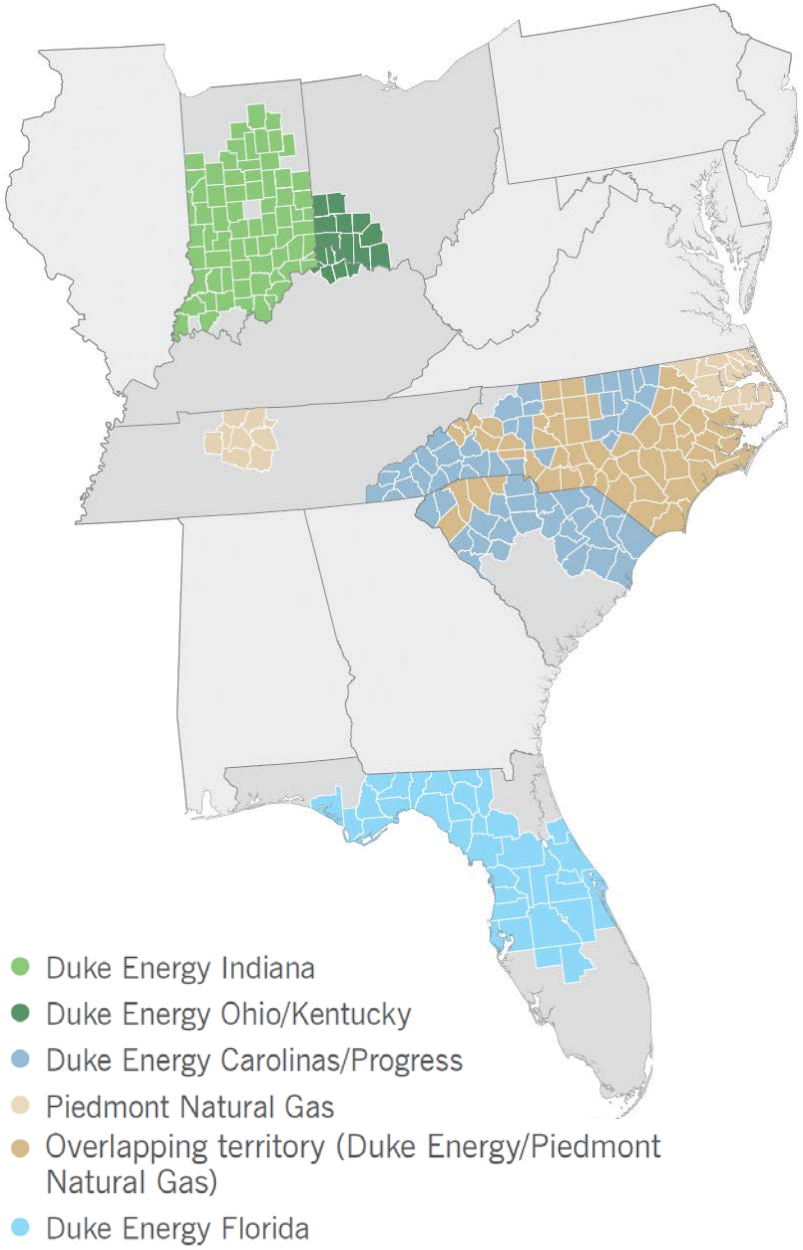
Duke Energy Emerging Technology Office

Open Field Message Bus (OpenFMB): Enabling Distributed Intelligence

Stuart Laval

About Duke Energy

- One of the Largest Electric Holding Companies in the United States
- Electric Utility operations in North and South Carolina, Indiana, Ohio, Kentucky, Tennessee, and Florida serving **7.5 million customers**
- **50,000 MW** of regulated generation
- **6,500 MW Renewables to Date:**
  - 3,000 MW of wind
  - 1000 MW of solar
  - 40 MW of battery energy storage
- **Renewable Goals:**
  - 8,000 MW of wind/solar/biomass by 2020
  - 300 MW of battery energy storage by 2025



Observations of Today's Utility OT and IT Systems

DER Management	≠	Virtual Power Plant or Load-Shedding
Distributed	≠	Decentralized or Hub-n-Spoke
Real-time	≠	Decisions >1 min
Peer-to-Peer	≠	Client/Server or Master/Slave
Grid Management	≠	Exclusively SCADA
Cybersecurity	≠	Firewall or VPN
Historian	≠	Data Lake or Cloud
Edge Analytics	≠	Forensics or Diagnostics

UCAIug: Supporting all Control Paradigms and Data Models

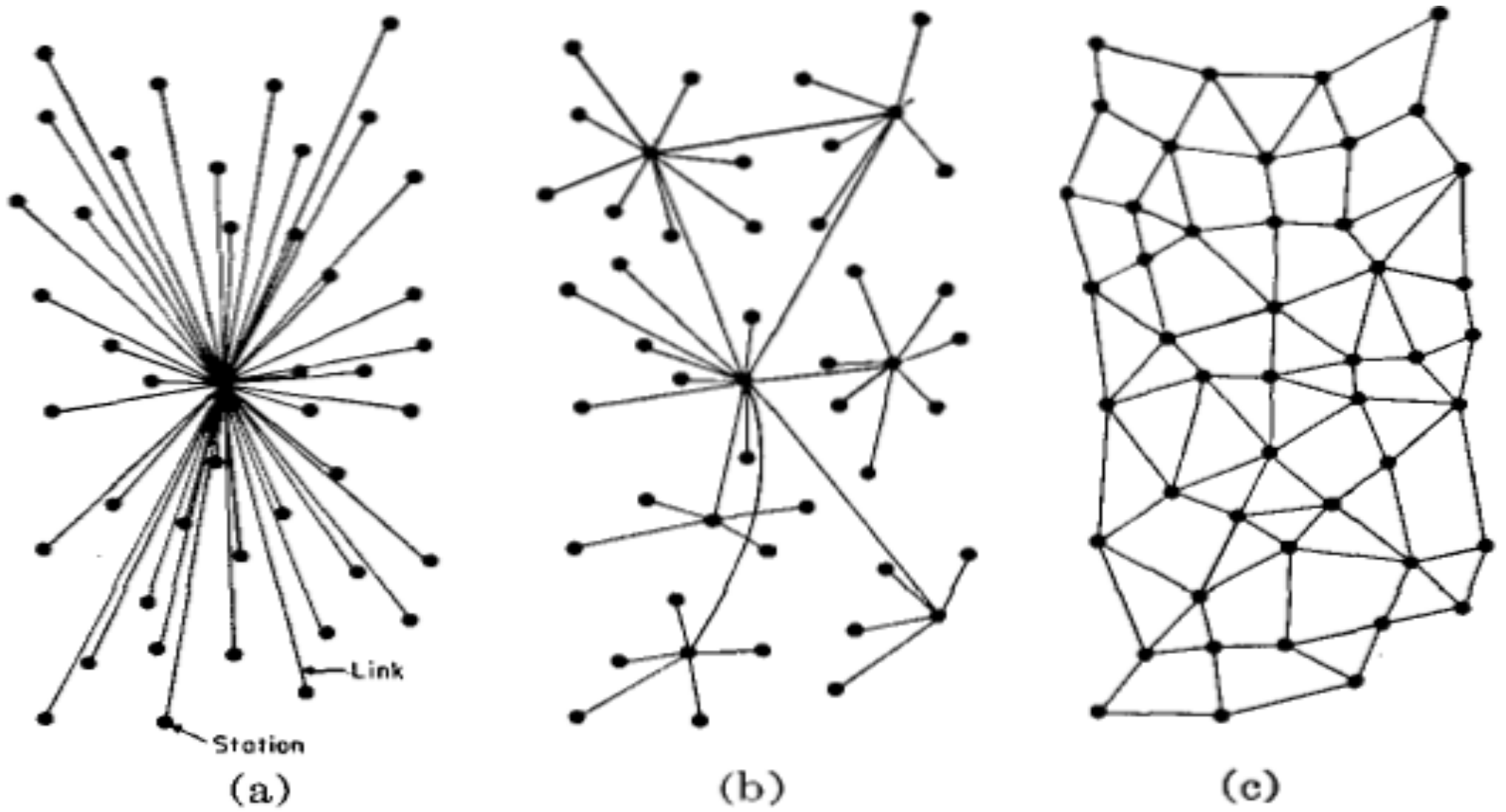


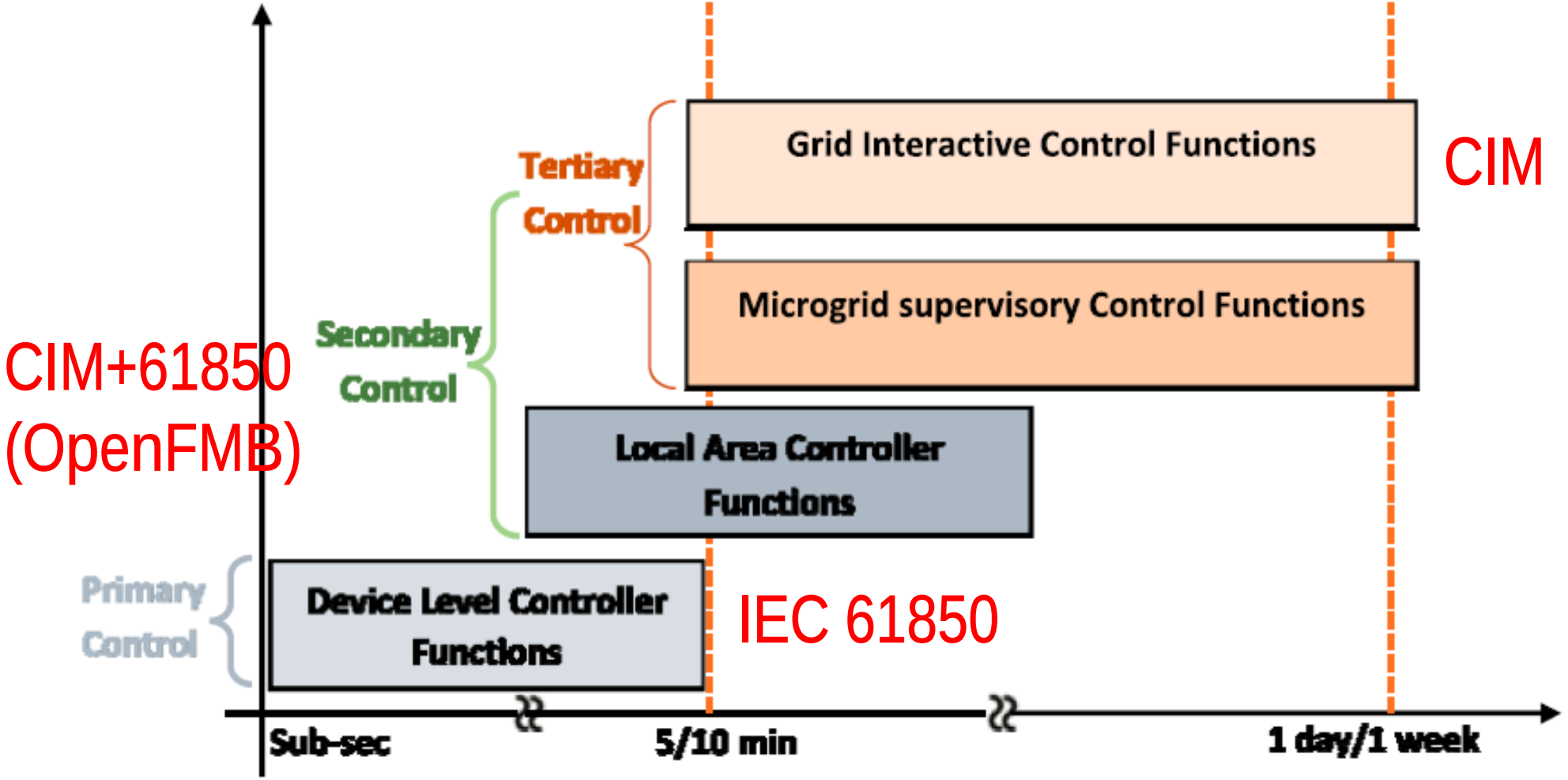
Fig. 1—(a) Centralized. (b) Decentralized. (c) Distributed networks.

Common Information Model (CIM)

IEC 61850

Open Field Message Bus (OpenFMB)

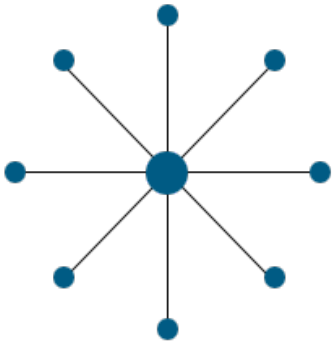
IEEE P2030.7: Example Hierarchy in Microgrid Controls

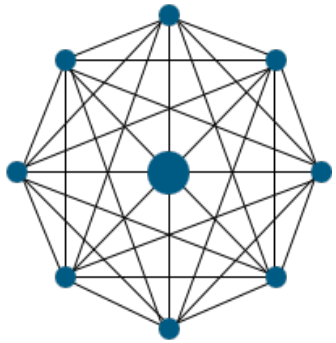


Source: IEEE

What is Distributed Intelligence?

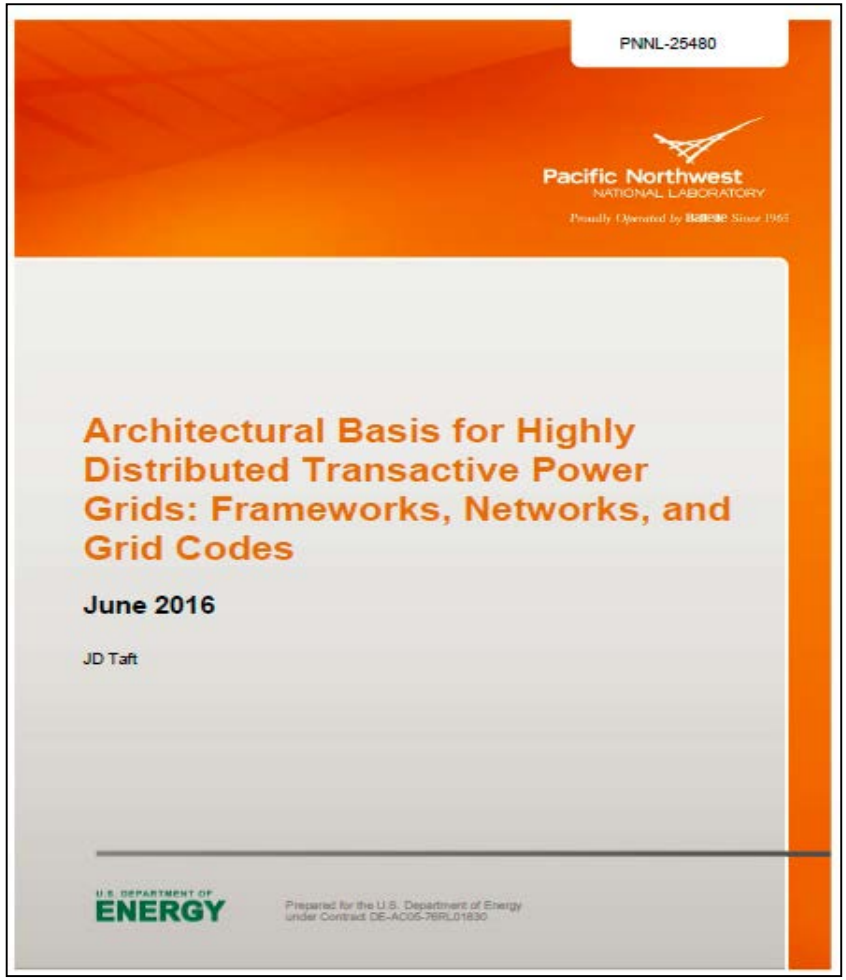
- Distributed Intelligence (DI) is a multi-layer, federated architecture that supports active coordination between multiple devices/systems to solve a common problem.
  - US Dept of Energy refers to as “Laminar Coordination”
  - Can occur at head-end, node, and grid-edge layers.
  - Location of decision can be optimized based on sensitivity, timeframe, system updates.
- Differences over traditional approaches
  - Supports stacked business use-cases
  - Enables edge interoperability and enhanced resiliency
  - Exception-based processing, distributed computing
  - Reduce backhaul bandwidth utilization
  - Does not rely on back office connectivity
- DI standard: NAESB’s Open Field Message Bus (OpenFMB)





Viable Distributed Intelligence (DI) Frameworks

DOE PNNL's Grid Architecture 2.0:
Laminar Coordination Framework (LCF)



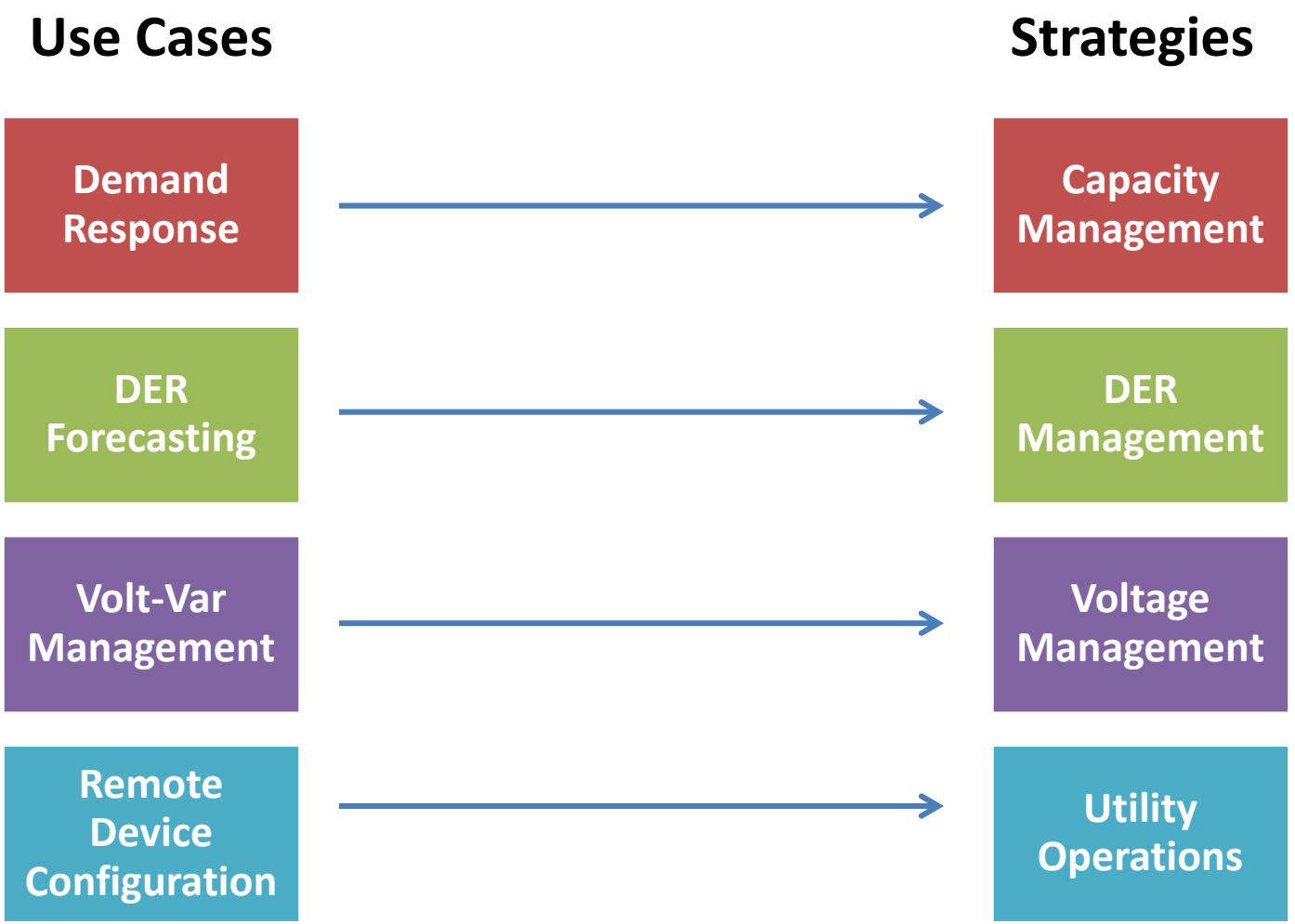
PNNL-25480 (Courtesy of JD Taft)
Available at http://gridarchitecture.pnnl.gov/

UCAIug's Open Field Message Bus (OpenFMB):
Internet of Things (IoT) Interoperability Framework

NAESB RMQ.26 Version 3.3
Please contact naesb@naesb.org

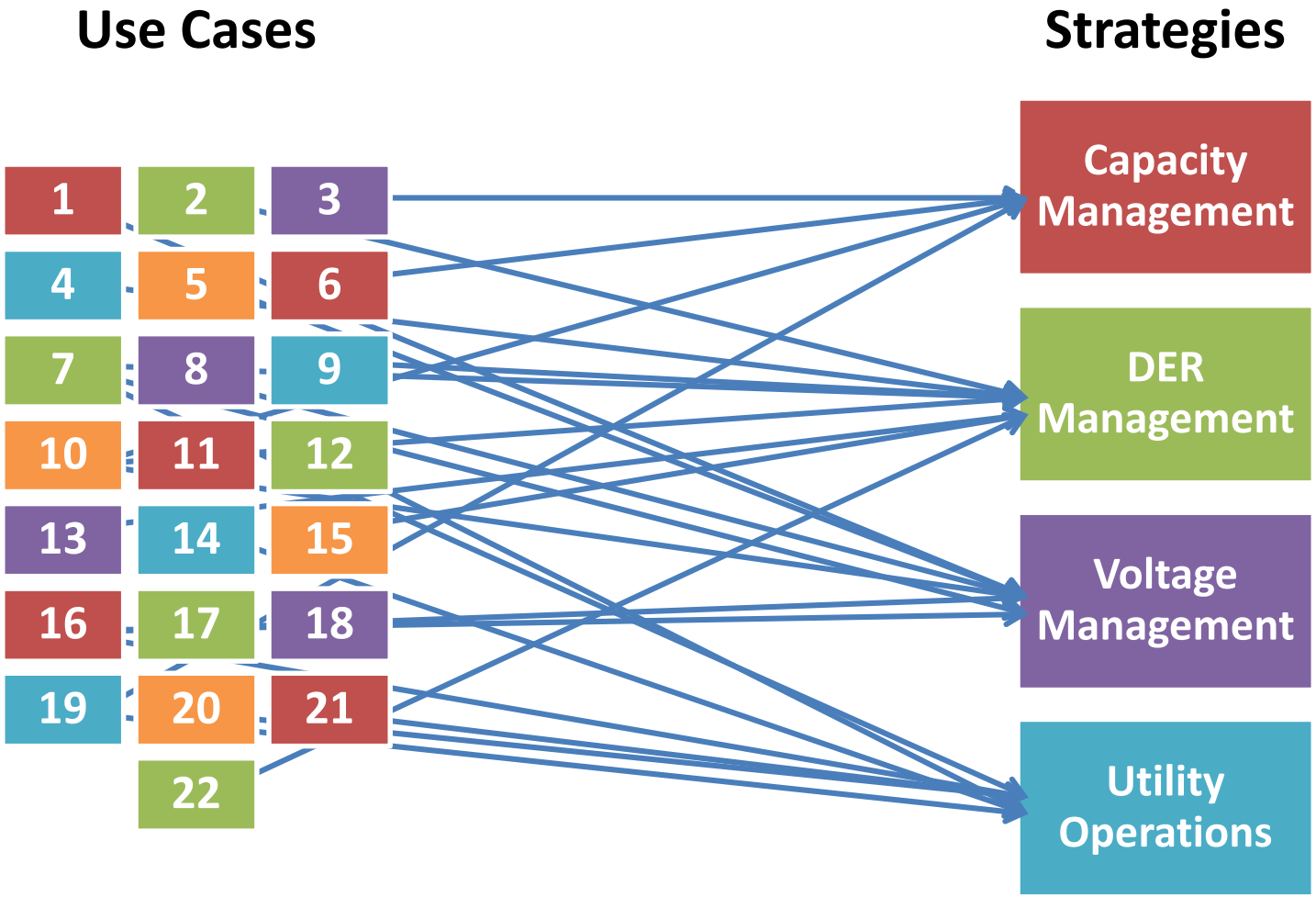
Traditional Approach

Conventional deployed assets support a single use case and outcome



Proposed Approach

Distributed Intelligence (DI) deployed assets support multiple use cases and outcomes leading to stacked benefits

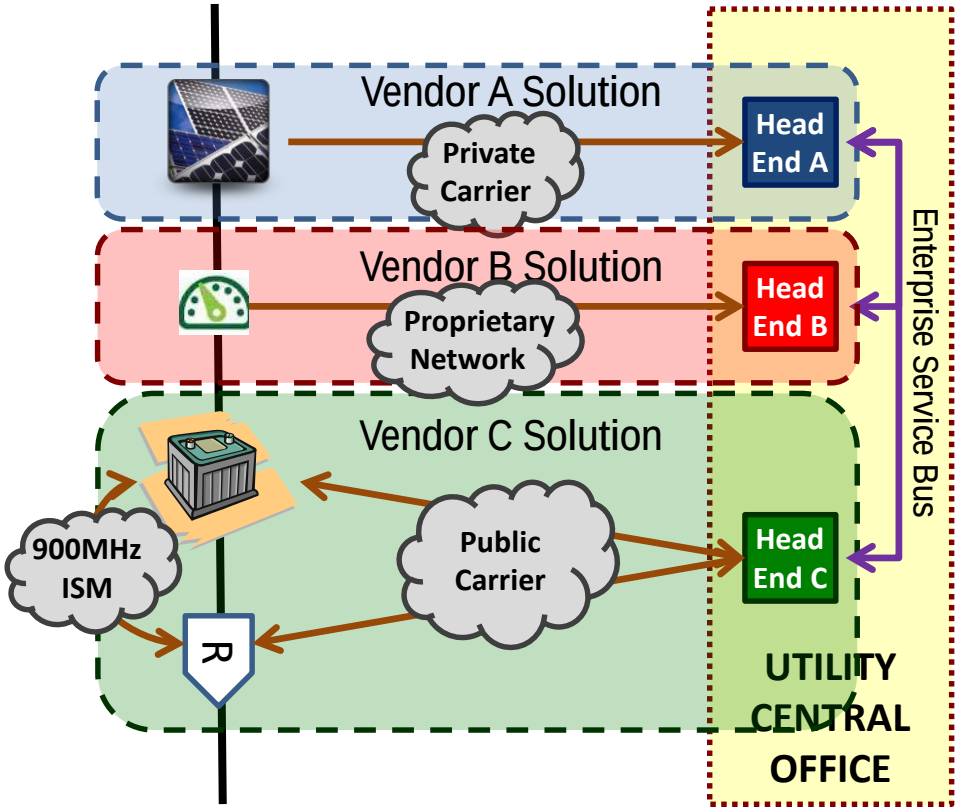


Stacking of Distributed Intelligence (DI) Use-cases

Of the 51 identified DI use-cases, 22 could be associated with a set of four deployment scenarios.

Use Case	Capacity Management	Voltage Management	DER Management	Utility Operations
DER Circuit Segment Management	✓	✓	✓	✓
Baseload Storage Monitoring/Mgmt.	✓		✓	
Peak Power Management	✓		✓	
DER Forecasting w/ Meters	✓		✓	
DER Forecasting w/ Weather Stations	✓		✓	
DER Optimization (Cust. Inverter)	✓		✓	
DER Optimization (DE Inverter)	✓		✓	
Demand Response Optimization	✓			
PCC Monitoring/Mgmt./Opt. (DE µgrid)	✓	✓	✓	
PCC Monitoring/Mgmt. (Cust. µgrid)	✓	✓	✓	
Volt/VAR Management	✓	✓	✓	✓
Grid Connectivity Discovery				✓
Remote Device Configuration			✓	✓
SCADA Point Aggregation			✓	✓
Enhanced COMS Network Ops. Status				✓
Improve Asset Maint. Practices				✓
Localized Protection Alarms & Events			✓	✓
Self Healing Radial Network			✓	✓
Solar Smoothing		✓	✓	
Solar Smoothing (+Battery)		✓	✓	
Inadvertent Island Detection			✓	
DER Integration & Interconnection			✓	

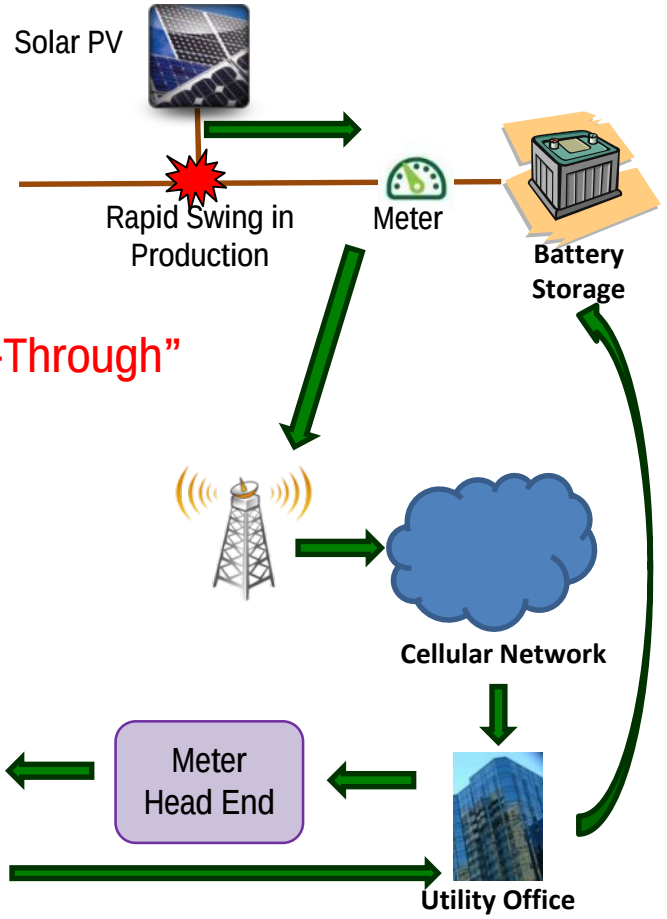
DER Challenges with Traditional Centralized Solutions



Key Observations:

1. Single-Purpose Functions
2. Proprietary & Silo'ed systems
3. Latent , Error-prone Data
4. OT/IT/Telecom Disconnected
5. No Field Interoperability!

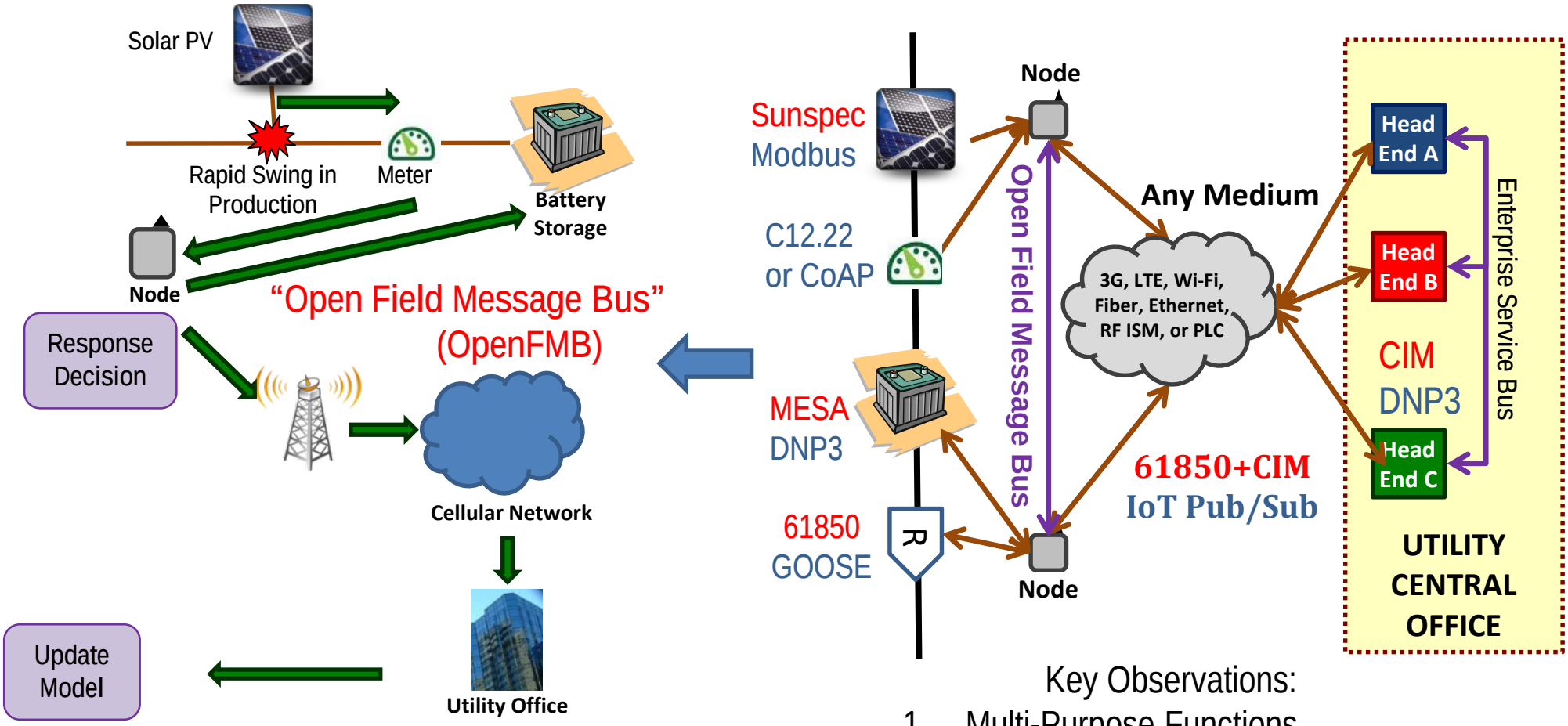
Present Day Smart Grid



Current State: Centralized Decisions

Slow, Raw, Stale, ***Unsecure*** Data

Unlocking data with an Open Field Message Bus (OpenFMB)



Future State: Distributed Decisions

Fast, Local, Actionable, ***Secure*** Data

Key Observations:

1. Multi-Purpose Functions
2. Modular & Scalable HW&SW
3. End-to-End Situational Awareness
4. OT/IT/Telecom Convergence
5. True Field Interoperability!

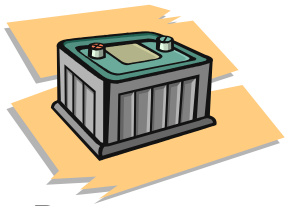
OpenFMB: Federated Deterministic Exchanges

- Periodic Readings - Pub every few secs or near-real-time
- Data-Driven Events – on status change in near-real-time

Readings
KW A/B/C
KVAR A/B/C
V A/B/C
I A/B/C
Phase Angle A/B/C
KWh
TimeStamp
State of Charge

Status, Events, Alarms, & Control
Trip / Open
TimeStamp


PV


Battery


Security/Network Policy Manager

Open Field Message Bus

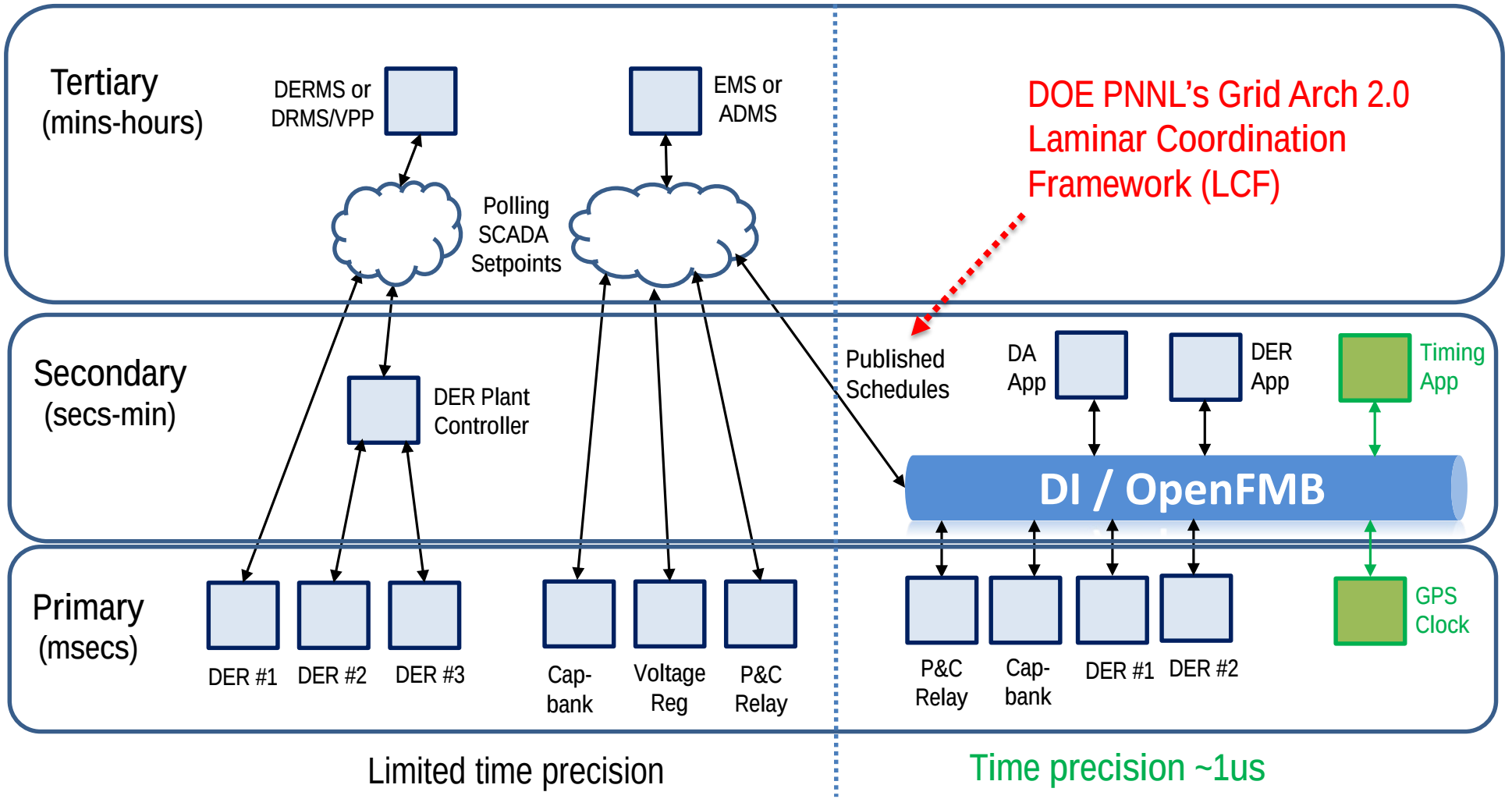

Recloser / Switch


Meter

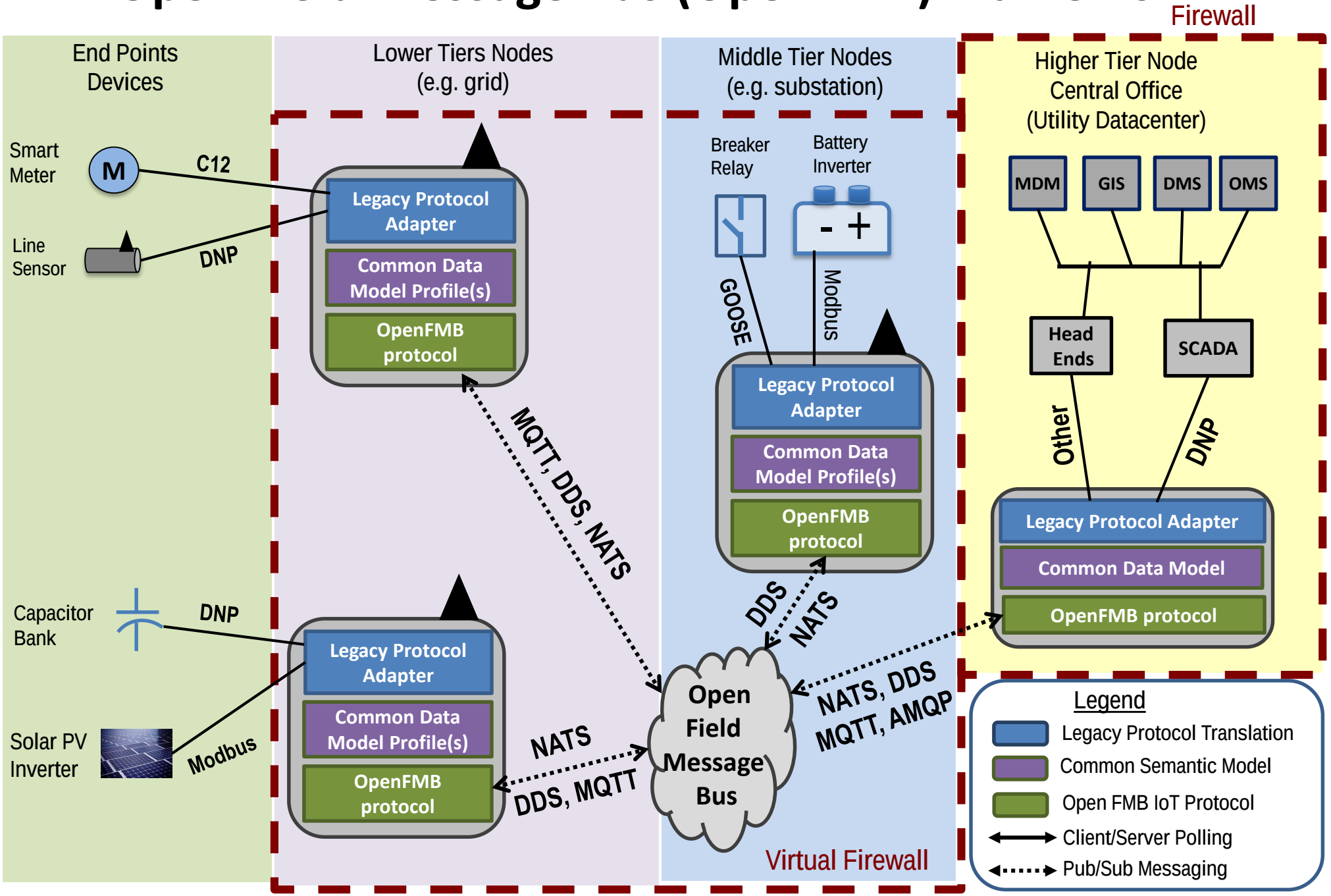

DER/Microgrid Optimizer

Grid Edge Analytics

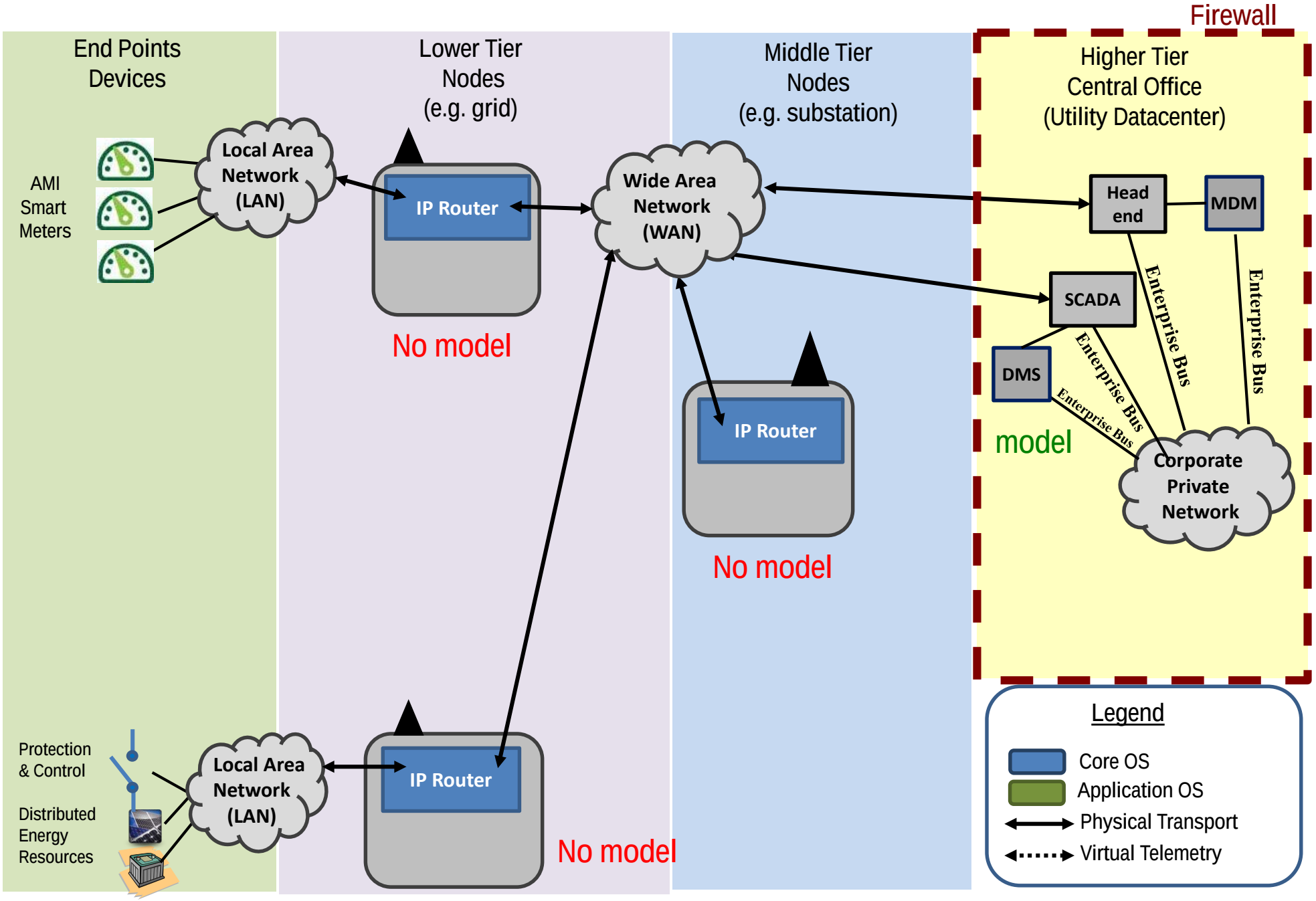
Co-Existence of Legacy and Future Controls



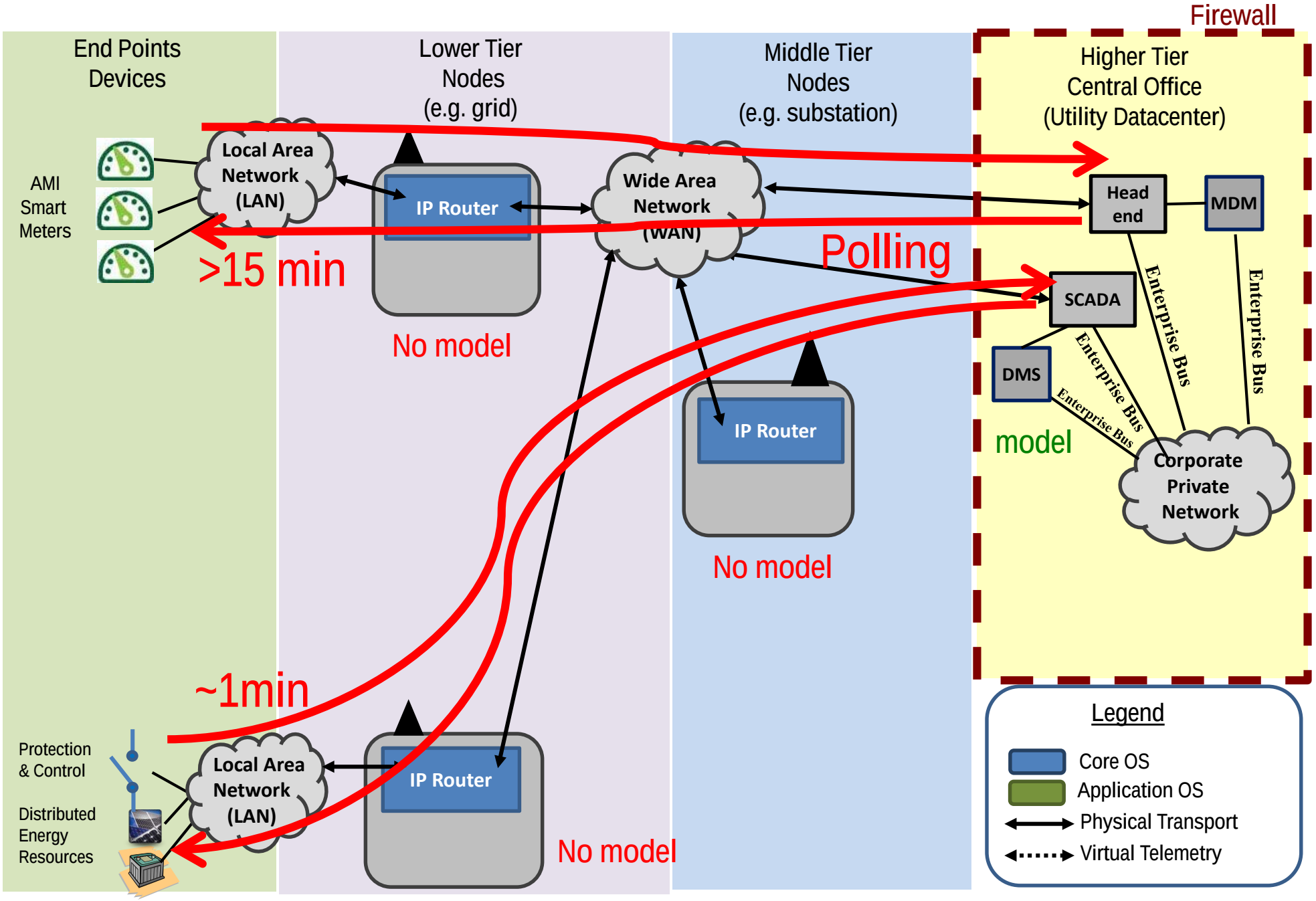
Open Field Message Bus (OpenFMB) Framework



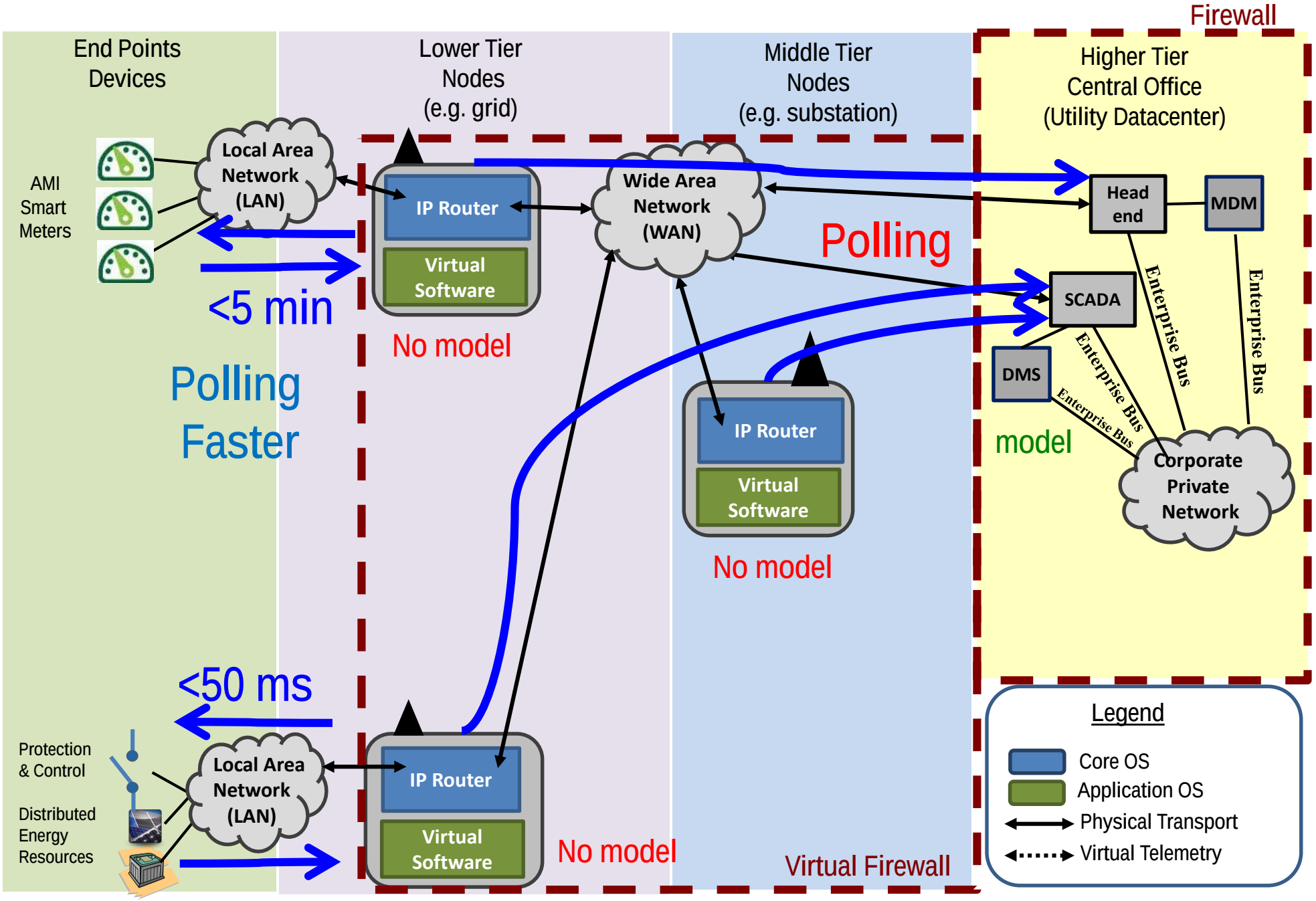
IIoT Reference Architecture: Existing Central Hierarchy



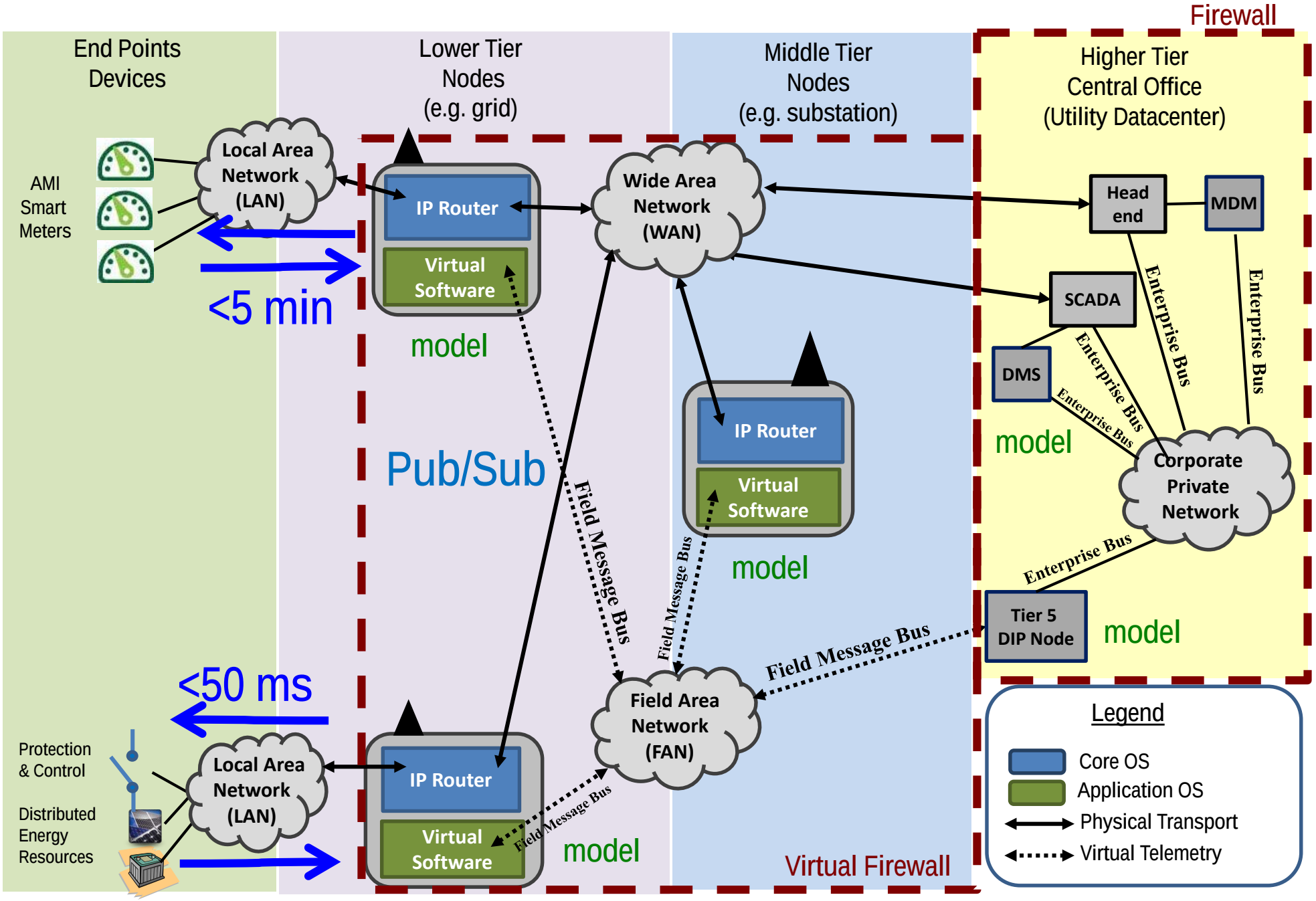
IIoT Reference Architecture: Existing Polling Operation



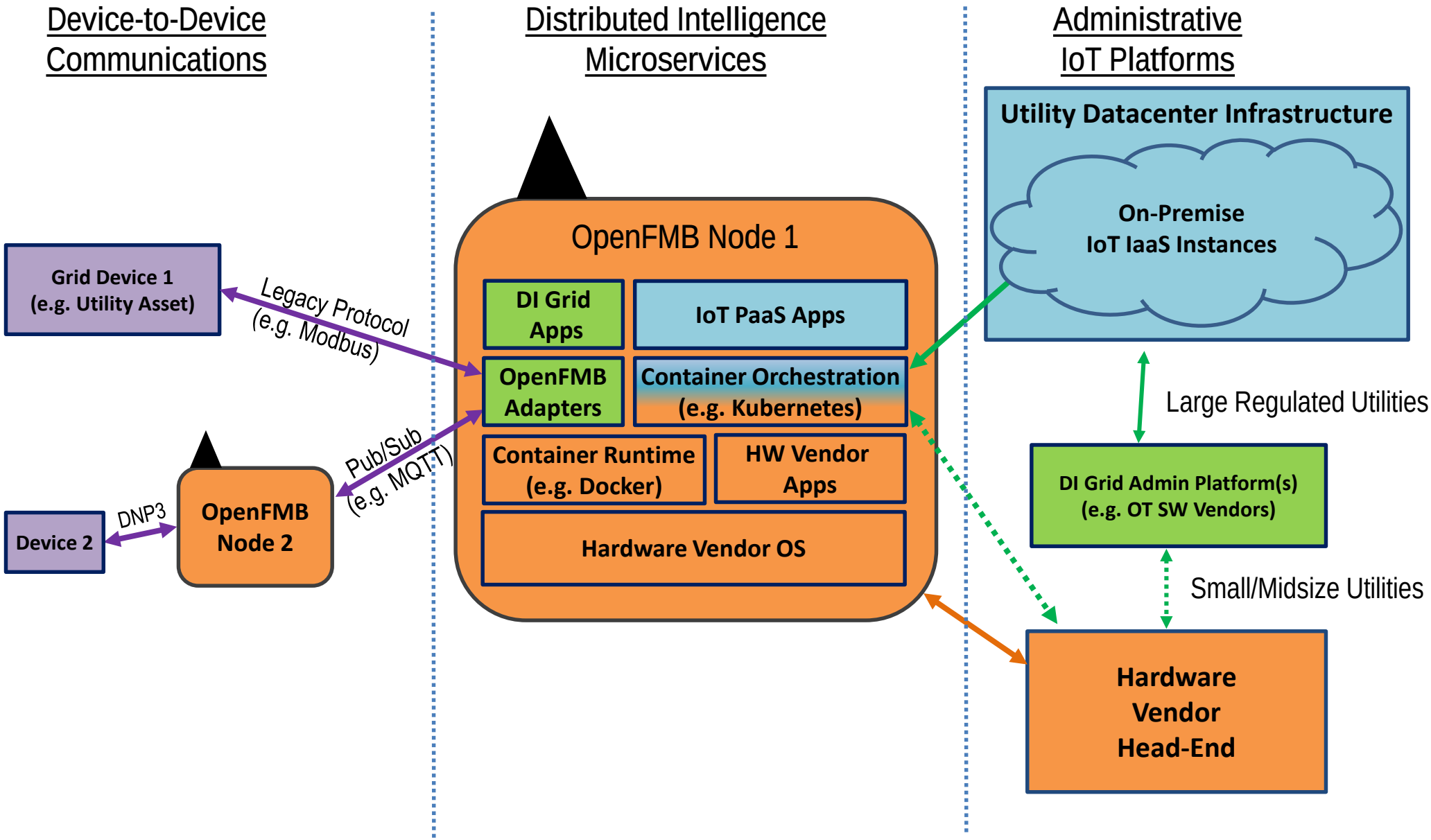
IIoT Reference Architecture: Hybrid Multi-level Hierarchy



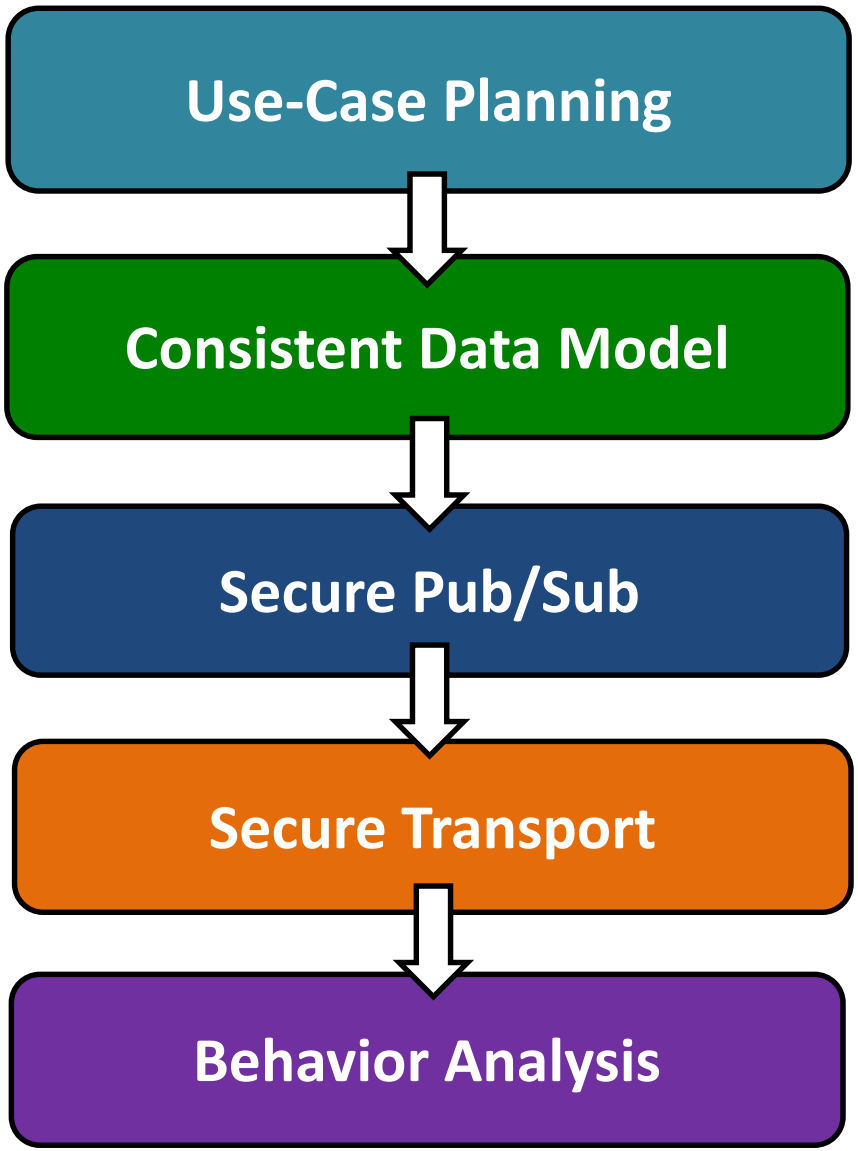
IIoT Reference Architecture: Hybrid OpenFMB Hierarchy



Co-existence of Multiple IoT Platforms



OpenFMB Security Analytics Framework



Describe

Identifying Normal Behavior & Good Actors: Commissioning, Updating & Operating.

Define

Profiles, Topics, Semantics, Behavior: Operational Functions & Security Policies

Messaging

White-listed & Encrypted Payloads: Pub/Sub on top of the UDP/IP or TCP/IP

Transport

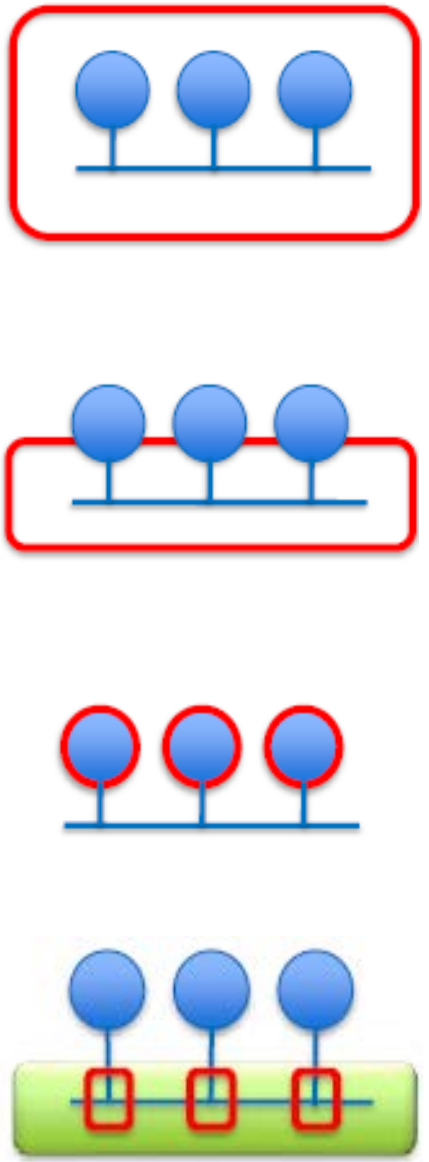
Transport Layer Security (TLS) 1.2 or later

Security Behavior Analysis

Intrusion Detection & Machine Learning: Domain Knowledge: Detect, Isolate, Restore

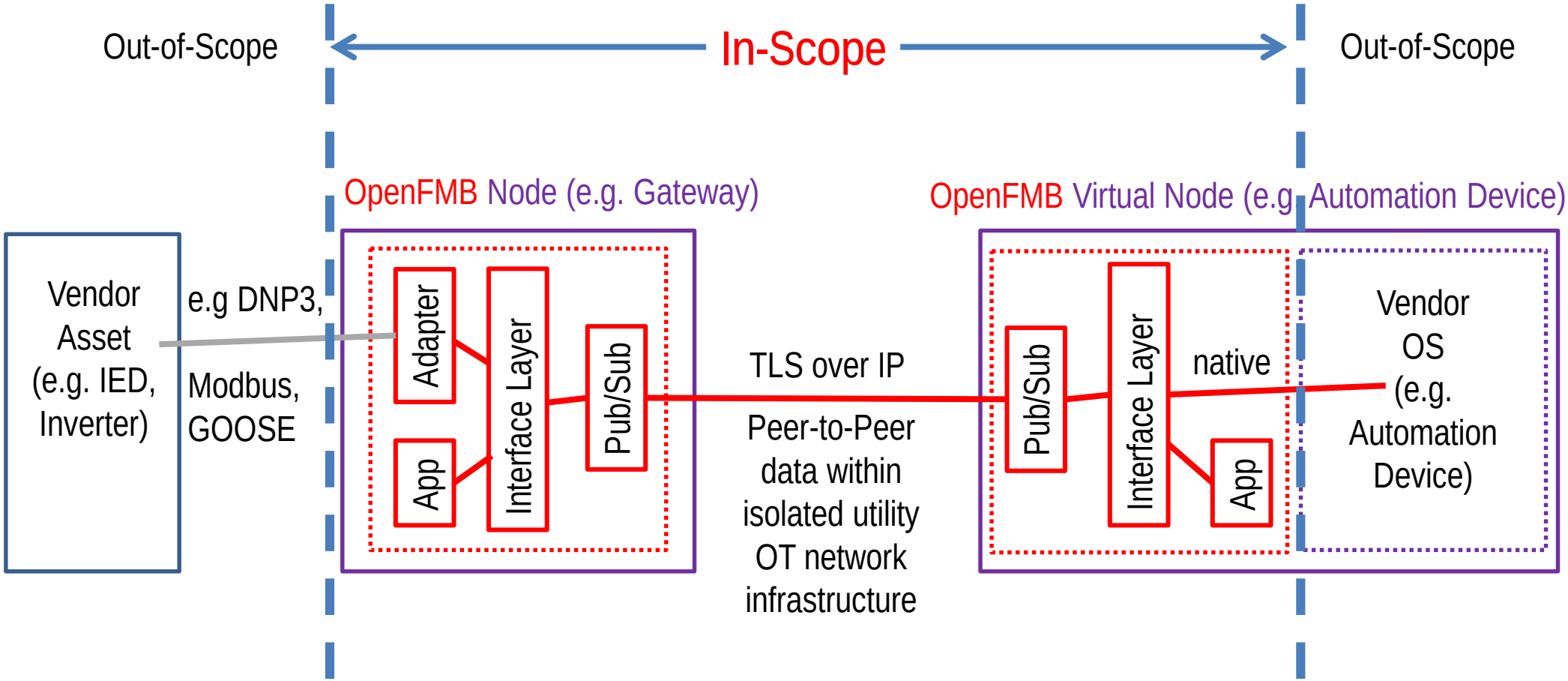
OpenFMB: Securing Multiple Boundaries

- System Boundary
- Network Transport
  - Media access (Layer 2)
  - Network security (Layer 3)
  - Transport Layer (Layer 4)
- Host
  - Machine/OS/Apps/Files
- Fine-Grained Data & Information Flows
  - Secure Topics
  - Addressed by DDS Security



Source: Real-time Innovations (RTI)

OpenFMB Node Secure Data Exchange



- OpenFMB Node: Can be Physical or Virtual (e.g. within containers)
- OpenFMB management services layer:
  - Manages root-of-trust usage and relevant certificates during TLS initialization (comms only)
  - Enables mutual authentication between nodes and between OpenFMB containers on the node
  - Updates apps/containers, patches, configuration parameters, etc.

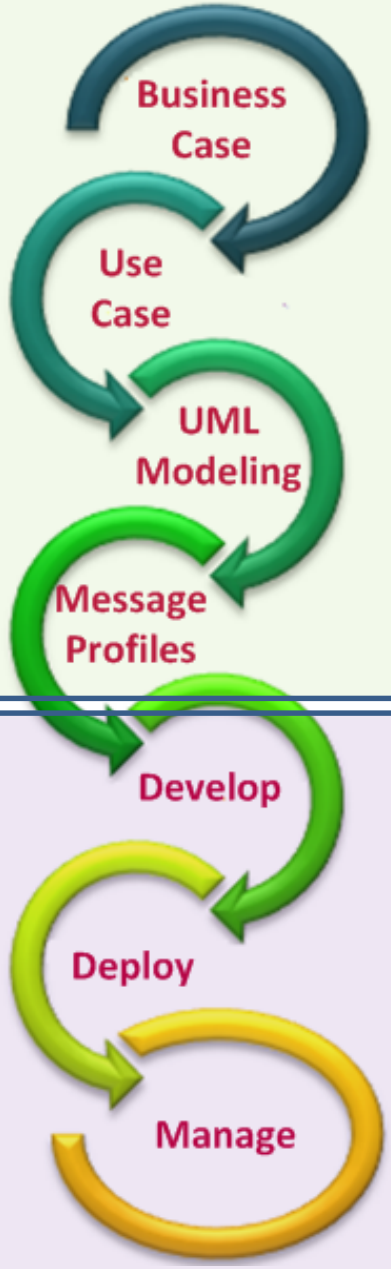
OpenFMB™: The Catalyst for Interoperability

- Open Field Message Bus (OpenFMB™) is a reference architecture and framework for distributed intelligence and grid-edge interoperability.
- Leverages existing standards to federate data between field devices and harmonize them with centralized systems
  - Utility industry standard semantic data models
    - IEC's Common Information Model (**CIM**), **IEC 61850**, and others.
  - Industrial Internet of Things (IIoT) publish/subscribe protocols
    - **Cloud Native Computing Foundation's NATS (nats.io)**
    - **OASIS's MQTT: Message Queue Telemetry Transport (mqtt.org)**
    - **Object Management Group's DDS: Data Distribution Service (omgwiki.org/dds)**
    - Other IoT pub/sub standard protocols being considered
- Scales operations independently, without a system-wide rollout
  - Flexible integration of renewables and storage with the existing grid
  - Accelerates ability to stack operational benefits
- OpenFMB standard ratified in March 2016 by the North American Energy Standards Board (NAESB). New RMQ.26 revision in Jan 2020.

OpenFMB Life Cycle Framework

Apache 2 Open-Source License
(OpenFMB CLA Required)

- Main and extension scenarios
- Platform Specific Models
  (e.g. IDL and Protobuf)



- Business-driven solutions
- Platform Independent Model
  (e.g. IEC CIM and 61850)
- Application and Adapter Configuration
  (e.g. DNP3, Modbus, and GOOSE)
- Health and lifecycle management

User Supported / 3rd-party Apps
(OpenFMB CLA Optional)

- Field Implementation

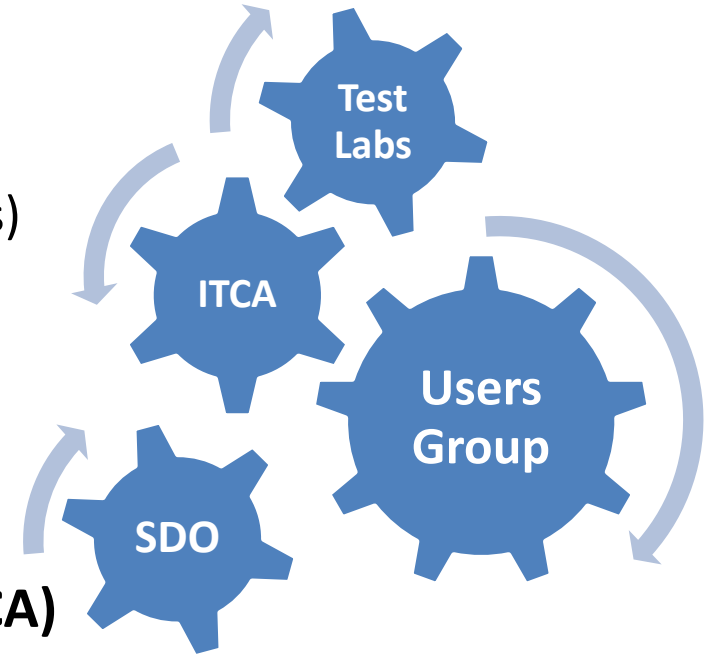
Key OpenFMB Organizations

- **Users Group**:
  - ***UCA International Users Group (UCAIug)***
  - Provides training, plug-fests, & marketing
  - Governs Open-Source artifacts (use-cases, data models)

- **Standards Development Organization (SDO)**:
  - ***North American Energy Standards Board (NAESB)***
  - Ratified NAESB RMQ.26 OpenFMB standard

- **Interoperability Testing & Certification Authority (ITCA)**
  - ***UCA International Users Group (UCAIug)***
  - Coordinates with Accredited Test Labs (ISO 17025) and Accreditation & Certification bodies (ISO 17065)

- **Accredited Test Labs**:
  - 1st Commercial Testing Lab: ***Battery Innovation Center***
  - https://www.bicindiana.com/bicopenfmb/
  - Implements and operates test harness for validating conformance to the OpenFMB test cases



First Annual UCAIug OpenFMB Plugfest

Date: Sept 24-26, 2019

Event Sponsored by:

UCA International Users Group

OPEN FMB

Event Hosted by:

UNC CHARLOTTE

Event Sponsors & Participants:

ABB

OBIC

CISCO

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DUKE ENERGY

EATON

Itron

OPEN ENERGY SOLUTIONS INC

Pacific Northwest NATIONAL LABORATORY

OAK RIDGE National Laboratory

SEL SCHWEITZER ENGINEERING LABORATORIES

SIERRA WIRELESS

smarter grid solutions

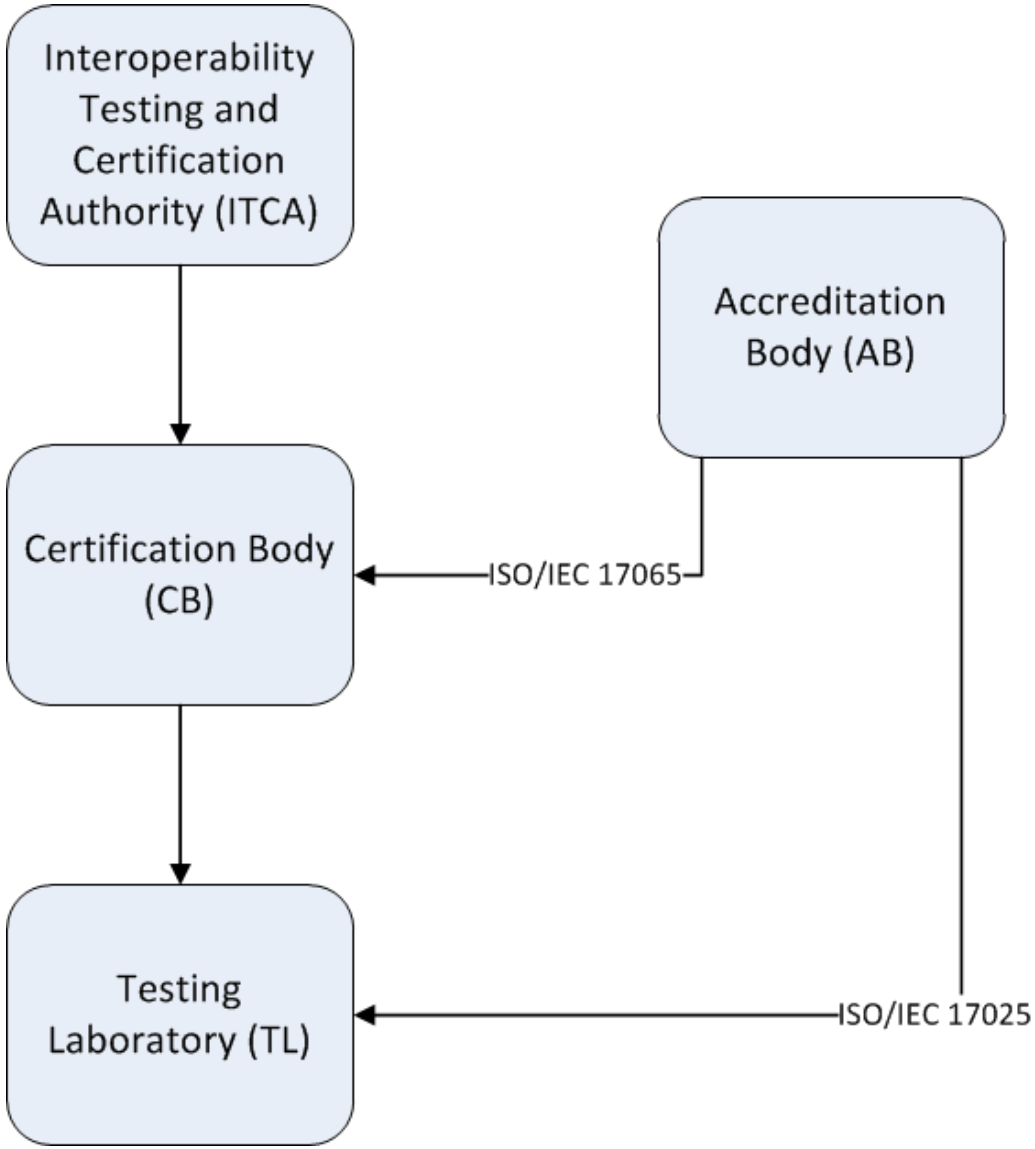
EPRI ELECTRIC POWER RESEARCH INSTITUTE

rti

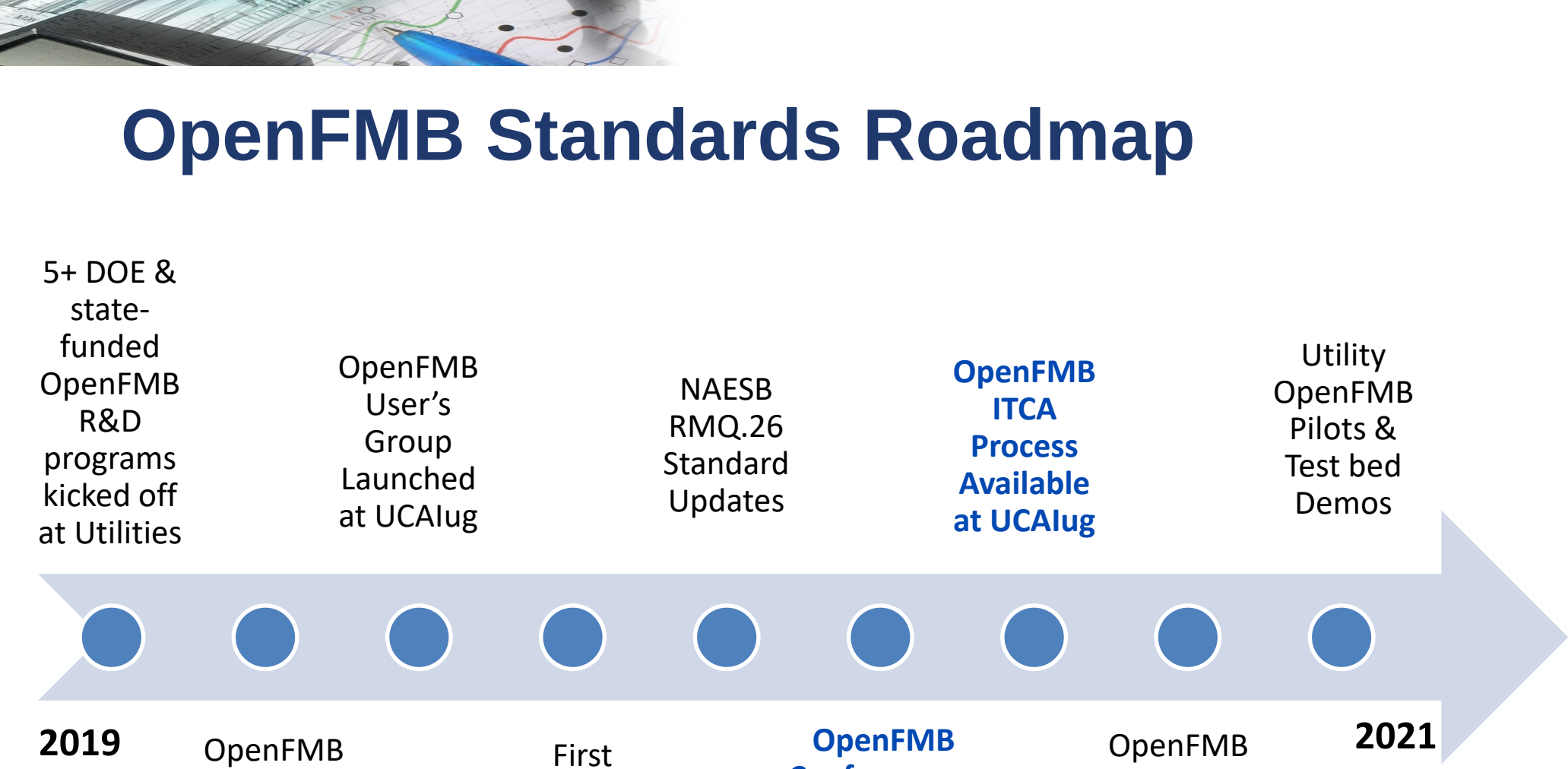
Xtensible A DOBLE COMPANY

Testing and Certification Structure

- ITCA – Interoperability Testing Certification Authority maintains certification program
- CB - Certification Body reviews testing laboratory reports and issues certificates
- TL - Testing Laboratory performs test cases against product
- AB - Accreditation Body accredits certification bodies and testing laboratories



OpenFMB Standards Roadmap



Legend:
UCAIug: Utility Communication Architecture International User's Group
NAESB: North American Energy Standards Board
UML: Unified Modeling Language
ITCA: Interoperability Testing & Certification Authority (ITCA)

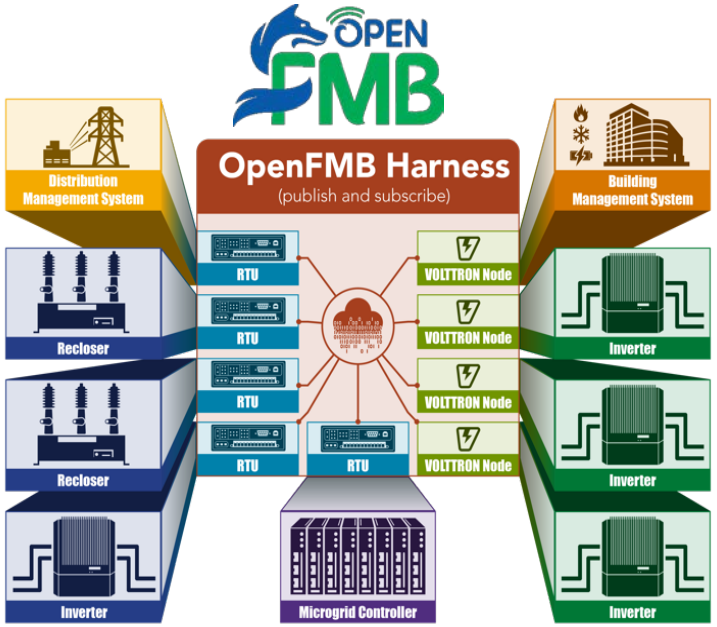
In-Flight OpenFMB Industry Efforts:

- Anticipated Benefits
  - Extending the capability of traditional utility operational systems
  - Improving visibility and performance of power system operations via more precise control and faster response time utilizing edge analytics
  - Autonomous remediation of load congestion to alleviate capacity
  - Harnessing edge computing for resilience and scalability
  - Enabling Flexible interconnection of DERs
  - Delivering low-latency power quality correction
  - Optimizing market participation between DR and DER schemes

- 5+ Investor-Owned Utilities initiating OpenFMB pilots
  - Integration of DERs (grid-scale PV/Storage) into Distribution system
  - Voltage & Outage Management with High-Penetration DERs
  - Microgrid islanding operation & optimization
  - Management of Networked/Nested Microgrids
  - Fault protection coordination with DMS & DERs/Microgrids

DOE Grid Modernization Lab Consortium (GMLC) Resilient Distribution Systems (RDS) Project Overview

- **Project Objective / Goals**
  - Accelerate Interoperability and Distributed Intelligence
  - Enable Flexible, Resilient, and Secure operation of traditional distribution assets with DERs, and microgrids.
  - Coordinate the operation of centralized self-healing with grid-edge DERs and microgrids to increase Resiliency.
  - Multi-layered OpenFMB Test Harness using COTS equipment
- **DOE Lab Open-Source Capabilities**
  - PNNL: LCF Architecture; HELICS Co-Simulator; VOLTTRON
  - ORNL: CSEISMIC microgrid controller; Si-Grid AC Emulator
  - NREL: ESIF Hardware-in-loop (HIL) Simulators
- **Industry Participant Expertise**
  - Duke Energy / SEPA – OpenFMB
  - GE Grid Solutions - ADMS
  - UNC-Charlotte/UT-Knoxville – RTDS/Opal-RT/Typhoon
- **Industry Advisory Board**
  - Avista, Arizona Public Service, Entergy
  - North American Energy Standards Board (NAESB)



DOE GMLC RDS Project Scope

➢Practical Use-Cases

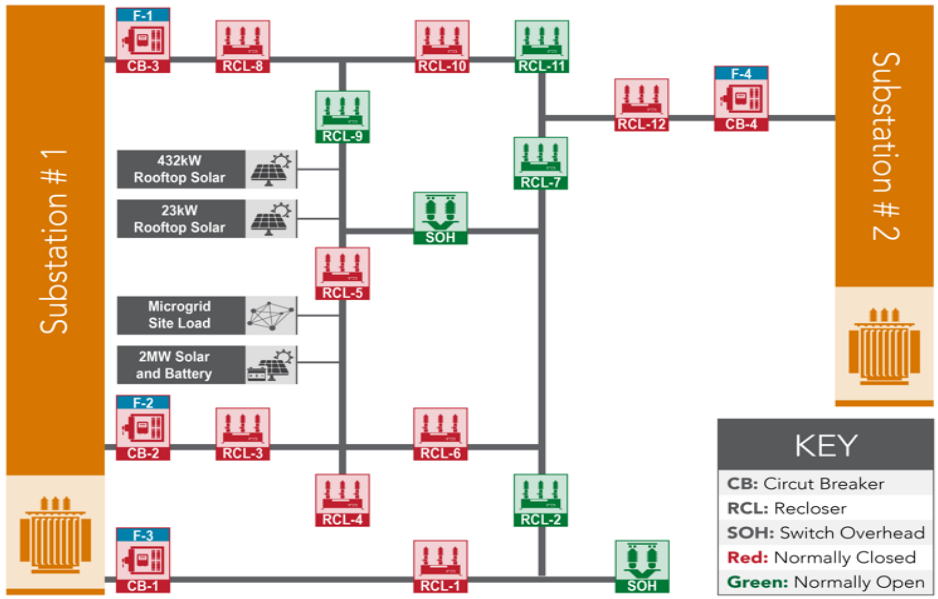
- ➢Segment-based Decentralized FLISR
- ➢Integrated DERs & Islandable Microgrid
- ➢Centralized ADMS Coordination
- ➢Incentive-based Optimization

➢Multi-Layered Controls

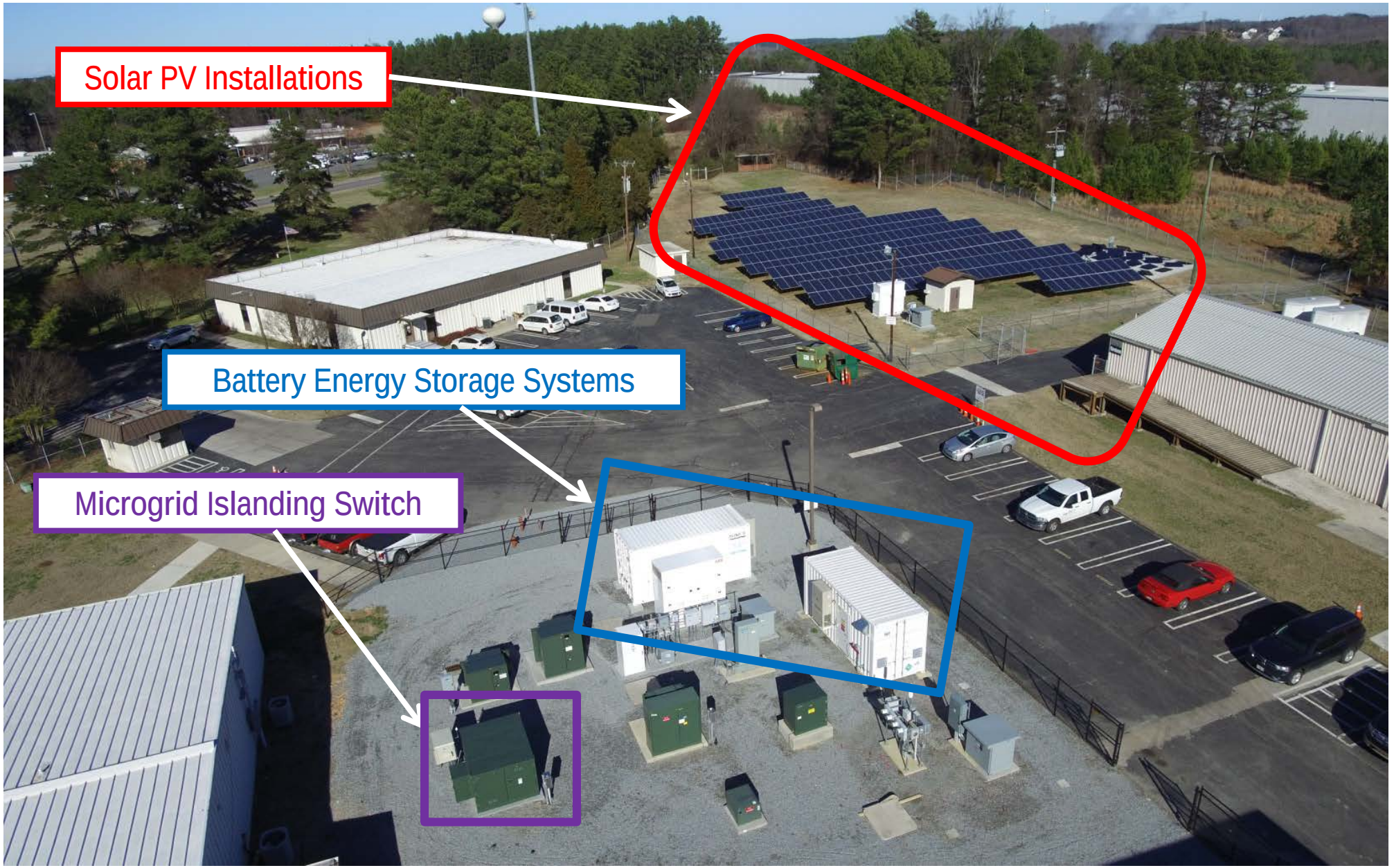
- ➢Layer 1: Local Breaker/Recloser Fault Isolation
- ➢Layer 2: OpenFMB for Protection Coordination
- ➢Layer 3: Centralized ADMS self-healing
- ➢Layer 4: Distributed Transactive Signal (Simulated)

➢Multi-Staged Validation Workflow

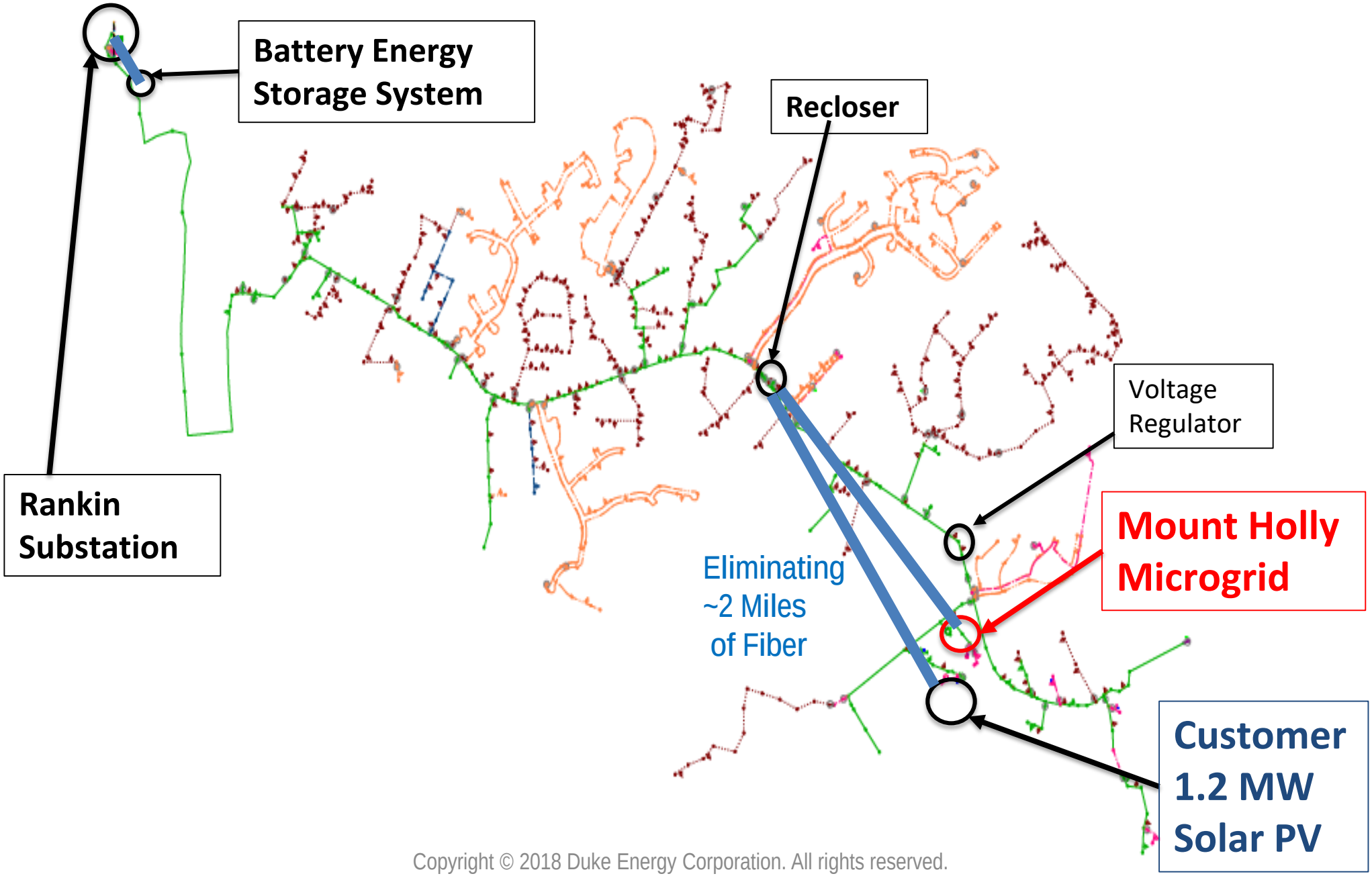
- ➢Co-Simulation
- ➢HIL-Simulation
- ➢Emulation
- ➢Implementation



Duke Energy Microgrid Test Site: Mount Holly, NC

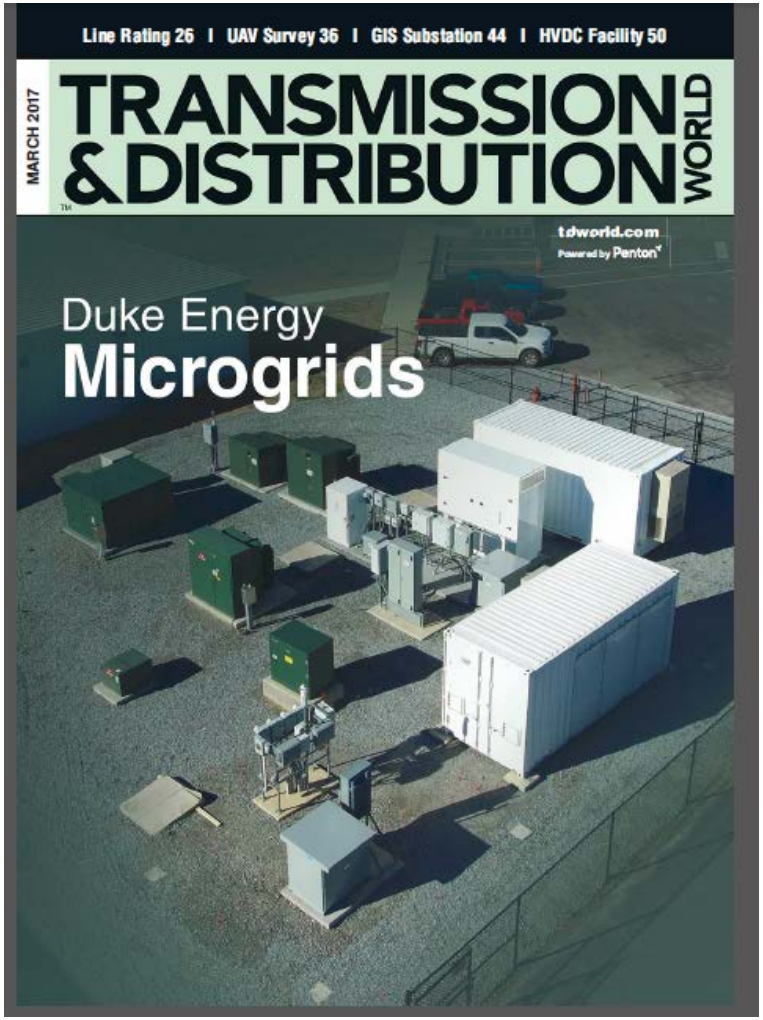


Example DER Anti-Islanding Use-Case to Eliminate Fiber



Duke Energy T&D World Publications

T&D World March 2017 issue



tdworld.com/march-2017

T&D World March 2019 issue


Avista Utilities and Duke Energy partner to create an energy operating system available to the entire utility industry.

By **Curtis Kirkeby**, Avista Utilities Inc., and **Stuart Laval**, Duke Energy Corp.

The electric utility industry is increasingly challenged by external drivers such as regulatory obligations and mandates as well as competitors who want to disintermediate utility customers from their current energy provider. Distribution system operator (DSO) models and aggregator participation are challenging the status quo for utility business models.

The utility industry must navigate these changes and help to shape the new business models while still providing safe, reliable and affordable energy to customers. At the same time, customer participation should be empowered, so there is reasonable influence on the type of resource consumed, the location of the resource, and who provides the energy. This is extremely challenging to support with a typical utility's portfolio of operating technologies.

Duke Energy Mount Holly, NC Microgrid Site.

May 2019 | T&D World 49

https://utilityanalytics.com/2019/06/utilities-collaborate-on-open-source-software/

Additional Information about OpenFMB:

- NAESB RMQ.26 OpenFMB standard publication
  - Contact naesb@naesb.org to obtain latest revision of the OpenFMB standard
- UCA OpenFMB Users Group Repositories
  - https://openfmb.io : OpenFMB open-source use-case & data model artifacts
  - https://openfmbusersgroup.slack.com : OpenFMB Users Group member internal site
  - https://openfmb.org: UCA public facing website for OpenFMB users group
- Upcoming UCA OpenFMB Users Group Face-to-Face Event
  - Finalizing OpenFMB Interoperability Testing & Certification Program
  - Hosted by the Battery Innovation Center in Newberry, Indiana on April 28-29, 2020
- For additional information on OpenFMB
  - Contact openfmb-admin@ucaiug.org

Thank You!

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